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THE STRATIGRAPHY OF THE PERMIAN WICHITA REDBEDS OF TEXAS[1]

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Abstract. A description is given of the topography of the limestones and sandstones that form the formation boundaries between the six units comprising the continental redbeds of north central Texas; the results are presented in two maps.

The Early Permian redbeds of Texas, those of the Clear Fork, and even more notably those of the still earlier Wichita Group, are of major importance in the history of vertebrates. These are the oldest beds in which there is present an abundant fauna of continental type. In earlier, Carboniferous deposits of various areas have been found a very considerable number of amphibian types, and even, in the late Carboniferous, early reptiles. But almost without exception Carboniferous deposits containing tetrapod vertebrates represent coal-swamp conditions, and it is not until we reach the Texas Wichita redbeds at the beginning of Permian times that we find a truly continental fauna. Specimens, to the number of several thousands, representing scores of amphibian and early reptile types, have been collected in these beds for nearly a century. It is clear that these beds, with more than a thousand feet of deposits, represent a very considerable period of time during which a fair amount of evolutionary progress and faunal change took place. Farther to the south and southwest the Wichita beds are mainly marine in nature, with identifiable limestones, and there competent stratigraphic work has been done. But with the transition to continental beds to the north and east the limestones fade out, and almost nothing

[1]This paper was in essentially completed form at the time of Professor Romer's death in November, 1973. Miss Nelda Wright kindly finished the task of preparing the manuscript and maps for publication. (Ed.)

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has been done in the past to sort out the sequence of formations in the redbeds portion of the Wichita.

In default of work here by the geologists, I decided a number of years ago (1960) that although not a stratigrapher or proper geologist, I myself must attempt to work out the sequence of formations in the Wichita beds.

The task, at first, seemed almost hopeless. Except on the fringes of the area, limestones, to serve as formation boundaries, were almost nonexistent. Sandstones could be observed here and there, but it seemed probable that these were channel sandstones of limited extent. The one saving grace was that almost all of the area concerned was oil-bearing, and that in consequence thousands of well logs were available. In these logs, identifiable limestone markers of late Carboniferous age could be located. Assuming (hopefully) that deposition of sediments was fairly uniform over the area concerned, it would be possible to lay out a sequence of formations by calculating the distance to the surface from such limestones and thus plot out a rough stratigraphic sequence.

A further discouragement lay in the fact that for almost all of the area no topographic maps were available. Apart from highway maps and blueprint land-ownership maps of the counties concerned (drawn up for the benefit of oil lease men), the only sources available were Department of Agriculture air photos, which show streams, hills and roads, but do not, of course, give any indications of elevation.

All in all, the prospect was most discouraging. But as I began work, I found that both nature and man rendered valuable aid. (1) As I said above, surface markers to distinguish formation boundaries appeared to be lacking. This proved, however, not to be the case. Upon study of the sandstones encountered, many of them proved to be wide ranging, and could be followed for a considerable distance cross country. Further, in most cases limestones that, to the southwest, were used as formation boundary markers, were found to change gradually to the northeast into sandy limestones, then into "limey" sandstones and straight sandstones, which could be traced across the entire area concerned.[1]

[1]Had I read more carefully Cummins' last paper (1897) on the Wichita-Albany problem, I would have seen my discovery of this condition to have been anticipated by him. He states: "We found that a limestone in the Albany Division . . . gradually changed in composition to a calcareous sandy clay. . . . other limestone beds in the Albany division when traced to the northeastward would gradually pass into sandstone."

(2) Major aid came from another source. As noted above, almost no topographic maps of the area were available when I began to work. At about this time, however, an arrangement was made between the Texas Water Development Board and the Topographic Branch of the U. S. Geological Survey, to map a larger area, including almost every bit of the Wichita redbeds region, on a scale of 1:24,000. The work proceeded rapidly and presently proofs and finally finished sheets of the whole area became available. These were of inestimable value to me — most notably in giving accurate elevations (doing elevations by aneroid in the highly variable weather conditions of the Texas prairies is most unsatisfactory).

(3) A final aid in this work came as a result of the decision of the Texas Bureau of Economic Geology to prepare a geological map of the State, at a scale of 1:250,000, under the direction of Virgil Barnes. One of the first sheeets attempted was the Sherman Sheet, along the north border of the State. The Cretaceous covers most of the territory, but much of the western margin, in Montague County, lay in the Permian. Almost no definite formation markers were available in this area, but it was found (as I had found) that certain sandstone beds could be traced for a considerable distance. These were followed out by J. H. McGowen westward across Montague County and into Clay County to the west. These sandstones were merely given numbers on the published Sherman Sheet; I found, however, that certain of them were identical with formation boundaries that I had been following eastward. In almost every instance, McGowen's findings and mine coincided. It was a pleasure to have my work independently confirmed and, in fact, in a few areas in Clay and Montague Counties, I saved my weary feet and accepted McGowen's findings in completing my course over to the Cretaceous boundary.

I owe thanks to a very considerable number of people and institutions for aid during the course of this work. Notably, I am deeply indebted to my wife, Ruth Hibbard Romer, who accompanied me on almost all of my trips to the area, furnished my transportation and day after day picked me up, footsore and weary, after a long trek across the cow pastures. John Kay, consulting geologist of Wichita Falls, who is an authority on the geology of the Wichita region, aided throughout with encouragement, advice, and specific data. The Gulf and Humble Oil companies gave me access to their well log collections and to unpublished maps, surface and subsurface, and the first-named

company presented me with a large collection of duplicate well logs. Robert Roth of Wichita Falls gave useful advice in Wichita stratigraphy. Robert Craig, oil geologist of Olney, gave me the use of a very valuable series of well logs of Young County. I am indebted to Frank Gouin, oil geologist of Duncan, Oklahoma, for interesting discussions of the Montague County beds. Virgil Barnes aided greatly by making available to me McGowen's tracings. Adolph H. Witte of Clay County, who has done much work in archaeology and paleontology, gave much helpful advice. The maps here published were drawn by Carol Jones.

I cannot refrain from mentioning the late Fred B. Plummer, of the University of Texas and the Bureau of Economic Geology, who first interested me in the stratigraphy of these beds and who, had he not died at an unseemly early age, would have been deeply interested in the present work.

It is impossible in a short space to give thanks to the many landowners who have allowed me to wander over their pastures. My wife and I are most especially indebted to Mr. and Mrs. G. F. Boone and L. D. Boone of Godwin Creek, whom we have long cherished as valued friends, to James R. Parkey who has given us ready access to various areas that he owns in the Little Wichita country, and John Robinson of Archer City, ever hospitable to "bone hunters."

I am much indebted to the National Science Foundation for support of part of my earlier Texas work, for support of a final trip to the Texas beds in 1973, and for publication of this paper.

WICHITA STRATIGRAPHY

The first student of the Wichita beds was W. F. Cummins. Originally a frontier preacher, he was engaged by Cope to collect fossil vertebrates in the Texas redbeds, then turned geologist, served on the Texas Geological Survey during the few years of its existence, and later became geologist for the Southern Pacific Railroad. In his early work for the Texas Survey, Cummins (1891) believed conditions to differ north and south of the Brazos River. He established a Cisco Division as forming the uppermost section of the Carboniferous in the northern area. Included in the Cisco were the coal beds (which he lumped at that time as "Coal number 7" and, as seen on his plate VII, considered the top of the Cisco to lie not far above this coal). The typical coals of this area are contained in the Harpersville

Formation of most writers. In the northern region he believed the Cisco to be directly overlain by the Wichita beds, which thus, as later identified, begin with the Pueblo Formation (in which are found the lowest redbeds in southeastern Archer County). In this northern area he believed the top of the Wichita beds to lie at a double limestone seen along the Big Wichita River a few miles west of the Archer-Baylor county line (1891: 402). This limestone is clearly the Bead Mountain Limestone, forming the boundary between Belle Plains and Clyde formations. Cummins' original Wichita thus included, in ascending order, the Pueblo-Moran-Putnam-Admiral-Belle Plains formations of later terminology; the Clyde Formation, later considered an integral part of the Wichita, was in this discussion thought to be a lower element of the Clear Fork.

Farther south, beyond the Brazos in Young and Stephens, Throckmorton and Shackleford counties, Cummins found a different situation. Above the Cisco are formations that are mainly marine in nature, which he did not realize were identical with his Wichita beds to the north. He believed these beds, which he termed the Albany Division, to be a terminal part of the Carboniferous intercalated between the Cisco and the Permian redbeds. The upper boundary of the Albany beds (1891: 404) he believed to lie between California Creek and the Clear Fork, about on the Shackelford-Haskell County boundary. He thus considered the Lueders as the top of his Albany beds, above which lay the Clear Fork redbeds.

Two years later (1893, especially p. 223) Cummins began to suspect that his Albany beds were merely a different facies of the Wichita beds. And in 1897 he confirms this suspicion, and definitely traces certain "Albany" beds northward into the "Wichita" region with a transformation of their character from marine to continental in nature. As a result, the term "Albany" was abandoned and the pre-Clear Fork Permian beds were termed Wichita — although some confusion remained as to boundaries between Cisco and Wichita and between Wichita and Clear Fork.

For many years little was added to our knowledge of these beds. Adams (1903) and Gordon (1911 (with others), 1913) confirmed Cummins' identification of the Wichita and Albany, and Gordon reasonably concluded that in the northern area the beds from the Bead Mountain Limestone to Lueders should be included in the Wichita.

A landmark in the history of the group was the publication in 1922 of "Stratigraphy of the Pennsylvanian Formations of North-Central Texas" by F. B. Plummer and R. C. Moore. While their attention was centered on the late Carboniferous, the Wichita formations were discussed as well. The beds which Cummins considered to constitute his Cisco division were divided, in ascending order, into the Graham, Thrifty, and Harpersville formations (the last including the coal beds). Cummins considered all higher beds as part of his Wichita. But since at the time of publication of Plummer and Moore's paper the Carboniferous-Permian boundary was believed to be at a considerably higher level, three further formations — Pueblo, Moran, and Putnam — were included by them in the Cisco, and only the formations lying above the Coleman Junction Limestone at the top of the Putnam Formation — Admiral, Belle Plains, and Clyde formations and, finally the Lueders Limestone — were considered to constitute the Wichita Group.

Subsequent to the publication of Plummer and Moore's basic work, the stratigraphy of the Cisco and Wichita has been discussed by a number of workers. For example, Sellards, in the comprehensive "Geology of Texas" (1933), follows in general Plummer and Moore, but since by that time it was generally agreed that the Carboniferous-Permian boundary had been placed too high in the section, the Moran and Putnam formations were included in the Wichita Group. In 1940, M. G. Cheney, oil geologist and an able student of Texas geology, proposed a radical change in treatment. Former "groups" became "series"; the former formations became "groups" and were subdivided into rather thin formations. During the years preceding this publication the invertebrate paleontologists had established a sequence of marine Permian beds in West Texas, termed the Wolfcamp and Leonard Series, the base of the Wolfcamp being considered the base of the Permian. Cheney proposed abandoning the established terms "Wichita" and "Clear Fork" and substituting the West Texas local terminology. The evidence of foraminifera indicates that the base of the Wolfcamp can be equated with a point in the Waldrip shales, somewhat below the top of Harpersville. Cheney solves this problem by abolishing the Harpersville "series," the top levels being included in the Pueblo, and the rest of the Harpersville being lumped with the Thrifty. The foraminiferal evidence indicates equivalence of the top of the Wolfcamp with about the middle Admiral. Cheney

hence reduced the Admiral by half, adding the upper part of the formation to the Belle Plains.

Moore returned to the Texas redbeds region in 1949 with the study of the geology of the Permian in the Colorado River region. He followed Cheney in part, by including the upper part of the Harpersville in the Pueblo, and including the upper part of the Admiral in the Belle Plains. However, he refused to raise the "formations" to "series" level. Furthermore, he retained the term "Wichita Group" for formations from the Pueblo Formation (expanded) to and including the Lueders, but parallels Cheney in also noting "beds of Wolfcamp age" and "beds of Leonard (?) age" at the levels given by Cheney.

In this present attempt at interpreting the stratigraphy of the Wichita beds, I have essentially followed Plummer and Moore. The finer subdivisions proposed by Cheney may be followed in the marine section, but are impossible to sleuth out in the continental beds. Nor can the subdivision proposed by him within the Harpersville and Admiral formations be readily followed in the continental areas with which we are concerned. I have adopted the base of the Pueblo as the base of the Wichita. This is in accord with Cummins' original definition of the Wichita, since the actual base of the redbeds type of deposit is at the base of the Pueblo Formation. Although I am far from certain that the base of the Wolfcamp of West Texas has any necessary relation to the true Carboniferous-Permian boundary, this equivalent is but slightly below the base of the Pueblo. It is generally overlooked by invertebrate paleontologists that, considering that the extent of the Permian was for a long time (and still is) a rather vague and ill-defined matter, the real point in question is not the base of the Permian but the top of the Carboniferous, a matter for settlement by paleobotanists. But both invertebrate and botanical evidence agree that the Permian base is a short distance below the base of the Pueblo, and since this exact point cannot be accurately determined in the continental beds, the slightly higher Saddle Creek Limestone, which can be readily followed, seems a satisfactory point for Cisco-Wichita division.

Methods. The results of my field work are shown on the three accompanying maps, on which I have attempted to exhibit the subdivision of the beds into six successive formations, from the underlying Cisco beds of the Carboniferous up to the Clyde Formation and the Lueders Limestones, which cap the Wichita

and form the boundary with the overlying Clear Fork. The formation boundaries, as traced, were at first entered on the air photographs, later on the 1 : 24,000 topographic sheets. It is, of course, impractical to publish them on this scale. Maps 2 and 3 are executed on a two-miles-to-the-inch scale, which will, I think, be sufficient for future workers to locate the horizon of their finds with reasonable accuracy.

The method followed was to pick up each successive limestone used as a formation boundary where already known and mapped, in the southwestern part of the region, and then follow it northward and eastward cross-country as it changed toward and to the condition of a sandstone. In some areas a continuous tracing was possible. Over much of the region, however, the rolling prairie surface makes this impossible, and I have had to seek out occasional small outcrops or detached slabs in the pasture grass, much in the fashion of a "paper chase." Under such conditions, of course, it was possible to stray from one sandstone to another, above or below. But over most of the territory there exists such a profusion of well logs that a check on elevations above the underlying limestones of the Cisco Group was present as a corrective.

All the stratigraphic studies mentioned earlier have been made in the region to the south of the true redbeds area; almost no previous attempts at stratigraphic subdivisions of the continental beds have been made. The sole exception was that in the 1920's, a time at which it was believed that the Coleman Junction Limestone represented the Carboniferous-Permian bondary, a reconnaissance was made of the probable course of this horizon from the point at which the limestone disappears in southwest Archer County north and east to the Red River (Timms, 1928). Some years ago (1958) in a general essay on the redbeds and their fauna I included a rough sketch of the probable formation boundaries in the redbeds area.

The general area to be considered is bounded on the north by the Red River; to the west by the Clear Fork beds above the Lueders Limestone, running north to south through Wilbarger, Baylor and Throckmorton counties. To the east, in Montague County, the Wichita beds disappear beneath the Cretaceous deposits. To the south we reach the base of the Wichita beds along a line somewhat south of the Jack County boundary. To the southwest the formations of the Wichita Group continue, but gradually change from continental to marine beds — that is,

from "Wichita" type beds to sediments of "Albany" nature. South of the Brazos River vertebrate fossils become scarce, and very few have been found in the Wichita beds beyond the southern boundary of Throckmorton County.

The geologic structure of the area is a simple one. The area is in general a northern continuation of the Bend arch. In eastern Young County and northward the beds dip to the north; west of this line, the dip is to the northwest (Hubbard and Thompson, 1926). In the southern part of the region the dip is on the order of 40–50 feet to the mile. Farther north the dip decreases, and in the upper beds, found on the surface toward the Red River, the beds are nearly horizontal. Near the river, the deeper beds in certain areas have been strongly affected by the east-west Electra arch and, farther east, by the Muenster arch. Arch activity, however, appears to have ceased before deposition of the surface beds here, and in general, these structures have had no effect on the surface stratigraphy. To the east, in southern Montague County we encounter the margin of the Fort Worth basin, with strong dips to the east and northeast in the lower beds.

One tends to think of the change in the nature of the Wichita beds as being a north-to-south shift from continental to marine. Actually it seems that it is an east-to-west transition. The general redbeds area appears to have been a lowland, with (presumably) high land to the east and a sea to the west. As is known from well logs, the Wichita redbeds formations became mainly marine west of a line extending from central Wilbarger County south through central Baylor and Throckmorton counties. In the eastern parts of these counties there are occasional persistent limestones, but redbeds tend to dominate and almost no limestones persist east of the east line of these counties.

As an aid to future workers who wish to check — or correct — my findings, I herewith add some detail as to the nature of my work on the various formation boundaries.

The Saddle Creek Limestone

As noted above, I consider the Pueblo Formation to be the basal member of the Wichita group; and I consider the Saddle Creek Limestone, at the top of the Harpersville, as furnishing a close approximation to the Carboniferous-Permian boundary.

The Saddle Creek Limestone is well developed in the more marine sections of the Wichita to the south, and can be followed

north as far as the Clear Fork of the Brazos, not far south of the Young County line. It can be traced into southwestern Young County only with difficulty and with doubt. Plummer and Moore identify it for a distance west of the Salt Fork southwest of Newcastle, but it is probable that this is the somewhat lower Belknap Limestone, as is also presumably the case of the supposed Saddle Creek in this area marked on the 1937 Cooperative geological map (Plummer and Fuqua, 1937). Lee and colleagues (1938; cf. Cheney, 1940: 91 and fig. 10) figure the Saddle Creek, although with some doubt, at the head of Ratliff Branch in southwestern Young County. Here the limestone, feebly developed, is part of a thick sandstone layer that can be readily followed to the north and east across Young County, where it lies in proper relation to the underlying limestones in the Harpersville.[1] From the point mentioned above, the sandstone beds here accepted as the Saddle Creek equivalent turn westward along the south margin of the valley of Gibbens Creek, cross that creek and run northeastward along the north side of this valley to reach a prominent bluff close to the Brazos and directly west of Fort Belknap. The Saddle Creek Limestone then turns west, and becoming less well marked, descends down the west side of the valley of Postoak Creek and reaches a bluff south of the Salt Fork at the mouth of Elm Creek. It continues west south of Elm Creek, to disappear into the Salt Fork alluvium about a mile east of Proffitt. The Saddle Creek reappears on the north bank, only obscurely west of the mouth of Paint Creek (California Creek), but east of that creek capping Deer Head Bluff north of the Salt Fork bottoms. East of this bluff it turns northward west of Big Skid Creek and can be traced with some difficulty eastward across the flat country at the head of this creek and then southward along a low ridge west of Peveler Creek. Returning northward to cross this last creek, the outcrop continues eastward along the hills north of Newcastle to a prominent point about four miles northeast of Newcastle and a mile west of Salt Creek. From this point a series of outliers extends northeastward toward Jean, but the main outcrop

[1]Galloway, in an interesting study of the Harpersville in subsurface (Galloway and Brown, 1972), gives a surface map on which the assumed Saddle Creek Limestone is shown for several areas in Young and Jack counties. Different areas indicated on this map, however, show the supposed Saddle Creek at several different levels, ranging from that of my assumed Saddle Creek up to that of the Camp Colorado, nearly 200 feet higher.

turns northward along the west margin of the Salt Creek valley, descending to cross this creek a mile northeast of True cemetery. The outcrop turns southeastward for two miles, swings northward to cross Little Salt Creek, then southward and again northward to obscurely circumnavigate a flat area east of Jean. The outcrop turns south for about three miles, then north for six miles to Farmer, at a level of about 1150 feet, mainly following the base of the hills west of the road leading from State Highway 199 north to Farmer.

Southeast of this area, the country rises to the Loving region. My well records for this area are sparse, but it seems probable that there were several outliers of the Saddle Creek in this area, the principal ones being at the Loving settlement and along a ridge running eastward toward the county line. Galloway (Galloway and Brown, 1972) considers these beds to lie within the underlying Harpersville Formation, presumably because he generally places the Saddle Creek member at a higher level stratigraphically than I do.

From Farmer the main outcrop runs eastward two miles along a ridge between two tributaries of Brushy Creek, then westward south of these tributaries to a point north of Farmer. North of this tributary it runs eastward along a ridge, which becomes prominently developed, for about three miles, with outliers on Rattlesnake Mountain and Bare Mountain, and then turns northward, only to turn westward up a further northern branch of Brushy Creek. After crossing this branch near its head, the Saddle Creek comes east again several miles to Spy Knob. Thence the outcrop runs for some miles northwest, then northeast, then southeast, in so doing outlining a semicircle around the margins of the Prideaux structure (highly important in the days of shallow oil production). After crossing the Windthorst-Loving highway, the Saddle Creek outcrop (now in southeastern Archer County) runs eastward along the southern margin of a ridge for several miles, almost reaching the West Fork of the Trinity River. It then returns westward north of this ridge and then turns north and northwest, to subside to the level of the West Fork near its crossing by the Windthorst-Loving road, at about 1,000 feet.

We are now entering a wild region, where the West Fork and its tributaries have cut deep valleys, capped by sandstones and covered by scrub oak and tangles of vines, making a very complicated pattern. As noted below, the main outcrop of the Saddle

Creek extends eastward north of the West Fork along a general line south of the north border of Jack County, with a general elevation of about 1,000 feet close to the county boundary, but somewhat higher farther south. To the south, beyond the West Fork, are large areas of hills and plateaus, sandstone capped, which lie at higher levels, and which, by such well-log evidence as is available to me, indicate them to be extensive outliers of the Saddle Creek.[1] The most westerly of major outliers of this sort is one whose southwestern extremity is at Markley and extends northeast about five miles to a point south of the mouth of Brushy Creek and runs eastward a similar distance along the north side of Plum Creek. Much larger is a tableland that occupies the area between the valleys of Plum Creek and Cameron Creek and extends from three to five miles south of the West Fork and includes an area of 20 square miles or so. Farther east a smaller outlier lies between Cameron Creek and Roberts Prairie Branch and a final, still smaller, outlier is found east of this branch. Farther southeast, it is probable that the top of the Indian Hills attains the Saddle Creek level.

After crossing the West Fork, the main outcrop of the Saddle Creek, as noted above, runs eastward, roughly parallel to the Jack-Clay county boundary and some miles to the south. For the first mile or so below the crossing there is little evidence of the presence of the Saddle Creek in the alluvial river bottom, but east of the Jack County line it is visible as a sandstone low down toward the river level. Its eastward course is a zig-zag one, the outcrop running to the north up successive creek valleys and rising southward to bluffs north of the West Fork. A mile east of the Antelope-Jacksboro highway it extends a mile to the north up the valley of Flat Creek, where its elevation drops somewhat below 1,000 feet, and then returns southward to a river bluff at 1,040 feet — an elevation that matches that of the outlier south of the river. Four miles east of the highway crossing, it runs north a short distance in a valley in the Mount Lebo region, then returns south to cap a high river bluff at about 1,050 feet. A mile further east lies Lodge Creek, a major northern tributary of the West Fork; the outcrop extends north up

[1]Galloway (Galloway and Brown, 1972) believes these sandstones to lie within the Harpersville; but this belief is due to the fact that the outcrop to the north, which he indicates as the Saddle Creek, is quite surely the Camp Colorado, nearly 200 feet higher in the section.

this valley to well toward the county line southwest of Shannon, dropping below the 1,000-foot level in elevation. East of this creek the West Fork tends to swing to the southeast, and the main outcrop, continuing eastward, tends to leave the river, although east of Lodge Creek outliers form bluffs at about 1,050 to 1,080 feet. The Saddle Creek again extends well to the north up Turkey Creek, next to the east, but beyond this creek the outcrop turns eastward around the margins of the creek valley, sending, however, a high ridge southward and then westward to reach an elevation close to 1,100 feet. Next to the east is Jones Creek, which the Saddle Creek ascends to Postoak settlement. East of Postoak the Saddle Creek extends southward several miles along a high but narrow ridge, bifurcate distally, with an elevation now over 1,100 feet. East of this ridge the Saddle Creek runs northward up the north fork of Crooked Creek, to end in a "flat" about two miles in circumference, where there are few exposures except in road margins. Descending this creek branch, it runs about two miles east to ascend the east branch of Crooked Creek to a deep valley north of Galliher Mountain. East of this branch it runs southeast and east for about four miles along the summit of gentle slopes, past Truce church, rising as it goes, to reach a ridge at the southwest corner of Montague County at an elevation of about 1,150 feet. It then turns northward along a bluff for somewhat over two miles, losing altitude, to enter the southeast corner of Clay County at about 1,090 feet. There are certainly outliers to the northeast of this bluff, and I have mapped sandstone ledges here that are probably Saddle Creek equivalents. From the southeast corner of Clay County the Saddle Creek turns westward along the foot of the hills south of Newport.

From this point eastward my subsurface data are not sufficient for me to be certain of the position of the Saddle Creek. There is certainly a sharp dip to the northeast, where we are entering the Fort Worth basin. It appears to be represented in hills north and northeast of Newport along the course of Big Sandy Creek toward and to the Montague County line and on northeast to Prairie Branch. Crossing this branch it appears to be continued by sandstones following the north shores of Lake Amon G. Carter, and then following for some distance up the valleys of Jones Creek and East Jones Creek, disappears under the Cretaceous about four miles south of Bowie.

Camp Colorado Limestone

The uppermost member of the Pueblo Formation is the Camp Colorado Limestone, which separates the Pueblo from the Moran Formation. It has long been known farther south, and is rather incompletely shown on the southwestern part of the geological map of Young County (Plummer and Fuqua, 1937), running north close to the Throckmorton County line northward toward Elm Creek. From west of Murray in southwestern Young County, it runs northward about three miles along the west edge of the Fish Creek drainage area, then turns back southwest for two miles east of Dry Branch of Elm Creek, then traces northward west of Dry Branch on one side or the other of the county line. It follows the west side of Dry Branch almost to Elm Creek, ending this course in a prominent bluff. It then turns back south along gentle slopes east of Meyers Branch, which it crosses about two miles south of Elm Creek. The Camp Colorado is not exposed along its course down the west side of Meyers Branch except at the foot of the bluff west of the branch close to Elm Creek. A mile west of this point the Camp Colorado can be seen at the bottom of the channels of Elm Creek and its tributary Bush Knob Creek.

North of Elm Creek slopes are gentle, but occasional traces of the Camp Colorado can be made out as it runs northeastward, gaining slowly in elevation and for some distance lying close to the state highway from Newcastle to Throckmorton. By two miles east of the county line it can be traced along the slopes of low hills north of this highway. It then turns northward along a low bluff to disappear in the Brazos alluvium near the mouth of Boggy Creek. During this segment of its course the Camp Colorado is gradually losing its calcareous nature and is in process of changing into a sandstone.

The Camp Colorado reappears on the east bank of the Brazos a mile to the north, in a low bluff west of the mouth of Rabbit Creek. It is obscure in crossing this creek, but east of this it ascends up a small tributary of the creek to the divide between Rabbit and Paint creeks, with a large outlier to the south. It then runs about three miles to the northeast along the west slopes of the Paint Creek valley, crosses this creek and swings east and south to a prominent south-facing bluff on the Jeffries ranch. Here it sharply reverses direction, and runs north and somewhat east, descending to cross Salt Creek somewhat over a mile south of Olney. East of Salt Creek it swings for a mile up the valley

of Willow Pond Creek, then turns back southwest to run eastward along gentle slopes for two miles to Pleasant Valley church. It then turns northward and somewhat eastward (poorly exposed) for two miles to gain the east-west ridge separating the Brazos drainage from that of the West Fork of the Trinity River. It crosses to the north through a low spot in this ridge, but outliers extend eastward along this ridge for about four and one-half miles. The main outcrop turns west, not far from the Young-Archer County line, to swing around the headwaters of the South Fork of the West Fork of the Trinity River. It continues northeastward for about eight miles down the west side of this fork, with conspicuous outliers on the east side of this creek. Crossing the West Fork proper, it continues eastward on the side of this small river, keeping at a level of about 1,050 feet not far from the creek for about 10 miles. Beyond this point the West Branch is gradually descending and swinging to the southeast and the Camp Colorado, keeping at roughly 1,050 feet, gradually diverges from the river, running some distance up Waters Branch and Darnell Branch as it approaches the Archer-Clay County line. It runs eastward north of Antelope and here meets the westward end of a line Pss, traced by McGowen for the Sherman Sheet of the Texas geological map mentioned earlier. From this point eastward my tracing of the Camp Colorado outcrop and McGowen's Pss coincide almost perfectly (except that I am doubtful of certain southern outliers of his where, I think, the south-to-north dip of the beds is not fully taken into account). The outcrop continues eastward close to the Jack County-Clay County boundary, at an elevation close to 1,050 feet. It dips northward up the valley of Flat Creek, just east of Antelope, farther to the north up the valley of Willow Creek, west of Shannon and again up a small valley near that settlement. The outcrop continues east, at the top of low south-facing hills, turning north up the valley of Turkey Creek west of Prospect and, to a lesser degree, up a small branch east of that settlement. It then runs south two and one-half miles to a hill two miles west of Postoak and then runs northeast along the west slopes of Jones Creek for a half a dozen miles. Thence it continues eastward in an irregular course, again capping south-facing hills, for another half dozen miles, entering the drainage of Big Sandy Creek north of Newport. Near the Clay-Montague County line it turns west up the valley of Prairie Branch; it then follows eastward down the north side

of Prairie Branch to about the county line, then retreats northwest up a branch of this creek toward Vashti before returning eastward, and, after some miles, turning for some distance up East Prairie Branch for about one and one-half miles. East of this creek it runs eastward along bluffs well north of Lake Amon G. Carter (with a deep "incision" for Trail Creek). West of Briar Creek it swings northward for about four and one-half miles to a point west of Bowie, and then, after returning some distance down the east bank of this creek, turns eastward to end beneath the Cretaceous cover.

Sedwick Limestone

Sedwick limestone, being the upper element of the Moran Formation is, again, well developed in the counties to the southwest of the region with which we are here concerned. It is shown, in somewhat incomplete fashion, on the 1937 Throckmorton County map (Hornberger, 1937), running north and somewhat east toward Elm Creek. I began tracing this limestone at a point about two and one-half miles west of the Young-Throckmorton County line, and about three miles south of Elm Creek. The Sedwick here is following north a ridge between Meyers Branch and an unnamed small creek to the west. With a slight interruption the Sedwick follows this ridge to within about half a mile of Elm Creek and then turns back southwest to a crossing of this unnamed creek. I could not trace the Sedwick down the even slopes west of this creek until, within about a mile of Elm Creek, the limestone is seen on a low ridge. The Sedwick then turns back southwest, east of Bush Knob Creek, to cross that creek at about three and one-half miles south of its mouth. Subsurface logs indicate that it again turns northward, but I found no surface indication of it until it is exposed in the bed of Elm Creek at a ranch road crossing some miles to the northwest.

North of Elm Creek, in a fashion comparable to the Camp Colorado a few miles to the east, indications of the limestone gradually become apparent, and it gradually ascends the north slopes of the Elm Creek Valley in a zig-zag fashion, until, about a mile west of the county line, it crosses north out of the Elm Creek drainage into that of small western tributaries of the Brazos, along which it runs northward to Boggy Creek, east of Elbert. In this stretch the Sedwick maintains its character as

a somewhat sandy limestone, and is accompanied by a shale layer containing *Myalina*. At Boggy Creek it turns westward, and is traceable to a point south of Elbert. It is not exposed north of the creek, although the *Myalina* bed is definitely present. Two miles east of Elbert the Sedwick again becomes visible and can be followed to the west for three miles to a point south of Leopard Creek. For the next four miles north and northeast to a bluff on the west bank of the Brazos, little is seen of the Sedwick (now a calcareous sandstone), for a curious reason. A local rancher, now deceased, had apparently become deranged from his services in the First World War, and seems to have spent most of the remainder of his life building beautiful stone walls (which have no obvious function) and appears to have incorporated in them nearly all sandstones visible in the area.

The Sedwick appears at the base of the bluff mentioned above, and then disappears into the Brazos bottoms. A mile to the north, somewhat over a mile below the Spring Creek settlement, the Sedwick is seen emerging along a low bluff. From this point it runs eastward and northward, crossing Spring Creek and then following the north side of Bitter Creek. This is farming country, but the general course of the Sedwick can be followed from slabs of calcareous sandstones seen here and there in the fields and field margins. South of Bitter Creek are low hills, capped by sandstones that are obviously Sedwick outliers. More important, well logs strongly indicate that the sandstones capping the hills west of Padgett, several miles to the south, are also Sedwick outliers.

The Sedwick crosses Bitter Creek about four miles east-northeast of Spring Creek settlement and then turns south to become clearly visible in slopes lying along the Olney-Spring Creek highway. Farther east the country is quite flat, exposures are rare, and were it not for the aid of well logs it would have been extremely difficult to follow this bed. The course is slightly north of east, into the northwestern end of the Salt Creek drainage, to a point at the west end of the settled Olney area, then north past the Lutheran church into Archer County. The course now runs north along the west side of a narrow valley which is running northward toward the Little Wichita River. East of this valley there develops a large outlier bounded (except to the south) by well-developed bluffs. The main outcrop follows the valley northward to about four miles north of the Young-Archer County line, then turns southwest, circling most of the headwaters of

Mesquite Creek and the two Olney reservoirs. Following down the west side of these reservoirs, the outcrop continues north close to the paved north-south road (farm road 2178) for two and one-half miles, then turns east along the low divide between Mesquite Creek and the South Fork of the Little Wichita River to the region of their junction. Here the outcrop is nearly lost in the alluvium, but having crossed Cottonwood Creek, it runs southeastward east of that creek (with outliers to the south). South of Bobcat Bluff the outcrop swings east and north to the region of the former settlement of Anarene. We find here the watershed between the West Fork of the Trinity to the south and creeks tending north to the Little Wichita. The divide is marked by a west-east line of hills, and a long series of Sedwick outliers runs eastward along them to (and a bit beyond) the Archer-Clay County line. From Anarene the main outcrop (poorly indicated for some distance) runs northeastward down the west side of Onion Creek. The northern dip of the Sedwick and the gentle gradient of the creeks running north to the Little Wichita are almost equivalent, and the course of the Sedwick to the east, all the way to Montague County, is a complicated one, the outcrop dipping to the north in each creek valley, and returning south between creeks. The outcrop follows Onion Creek north to a point four miles southeast of Archer City, then retreats southeast for three and one-half miles, only to turn north again, to follow Little Onion Creek to within a mile of the Archer City-Windthorst highway. After a short retreat to the south, it again advances northward down the valley of West Little Postoak Creek to a point north of the highway. It then turns south, circling the Windthorst hill, and then (with faint outcrops for the most part) follows a tortuous course — for a short distance north down a tributary of East Little Postoak Creek, and, further to the east, a mile or more down the valley of that creek. East of Windthorst I find the west termination of McGowen's trace of his sandstone Pl, and his line is thus that of the Sedwick east of here.

The Sedwick sandstone now travels southeastward for half a dozen miles, with a major outlier to the south, paralleling the course of East Little Postoak Creek upward to its headwaters. Turning east, it dips slightly into the headwaters of Deer Creek, and then runs eastward to the East Fork of the Little Wichita. Here it performs a complicated course. The Sedwick Sandstone runs north some miles down the west bank of the fork, then

turns back west up Joy Creek past the settlement of that name; then back down the valley of the Fork five more miles, and up a western tributary to Midway School. Finally, after continuing obscurely some distance farther down the west side of the Fork, it turns southeast and ascends the east side of the East Fork Valley for some eight miles, leaving to the west a substantial outlier in the region of Friendship cemetery. From a point about two and one-half miles northwest of Vashti, it turns northward a short distance down Smith Creek, and then east across the Clay-Montague County line. The main line of outcrop now extends eastward across the headwaters of Belknap Creek, a southern tributary of the Red River, dipping down to the north along this creek and several of its tributaries before reaching the cover of the Cretaceous about five miles north of Bowie.

Coleman Junction Limestone

Capping the Putnam Formation and underlying the Admiral, Coleman Junction Limestone is shown with a considerable degree of accuracy on the geological map of Throckmorton County (Hornberger, 1937), running north-northeast from a point a short distance east of Throckmorton City to cross the Brazos west of Spring Creek settlement a few miles south of the Baylor County boundary. North of the river the Coleman Junction runs eastward, gradually rising in elevation, barely enters Young County at its northwest corner, and then continues northeast into Archer County rising gently as it goes, crossing Spring Creek and the headwaters of Bitter Creek to attain the level of the plateau east of Megargel, and, turning north, is present on eastward-facing bluffs about five miles east of Megargel (in an oil field that was highly important in the shallow oil days). The Coleman Junction has long been known to extend this far north and, as noted above, Timms in 1928 attempted to sleuth out the general continuation of this unit north, east and north to the Red River (cf. Sellards, 1933: fig. 11). Although this was hastily done, detailed tracing shows that the line he plotted was essentially correct. A sandy lime, turning gradually into sandstone, continues northeastward from this point, high up on the west slopes of the valley of the South Fork of the Little Wichita River, but gradually descending toward the left bank of the South Fork, to reach after 14 miles the west side of the fork about two and one-half miles west of Archer City, at the junc-

tion of state highway 25 and farm road 210. The outcrop turns west and then disappears into the alluvium of the Middle Fork. From this point east and northeast the line of the Coleman Junction equivalent, as proved by well logs, follows the valley of the Little Wichita east and northeast for more than 20 miles, to the one-time settlement of Halsell, in Clay County. It is possible that in part some of the lowest sandstones north of the river are at the Coleman Junction level; on the other hand, well logs prove the existence of a number of outliers of this sandstone to the south of the main "line of march," extending to the neighborhood of Archer City and to high buttes southwest of that town; further outliers are present south of the river west of Scotland.

At Halsell, exposures now concealed under the waters of Lake Arrowhead show the Coleman Junction equivalent to reappear on the east bank of the Little Wichita and run southwest, rising gently, for several miles. Emerging above the lake level, it swings east, along slopes following the north side of the Deer Creek valley which develop into good bluffs north of Deer Creek settlement. There I find the western end of McGowen's tracing of his sandstone P4, which is thus the Coleman Junction equivalent. Three miles west of Midway School the outcrop reaches a high point at the Myers triangulation marker and enters the drainage of the East Fork of the Little Wichita. The Coleman Junction now follows down the west side of this valley in an irregular northeasterly direction for about nine miles to a point opposite Kola siding on the Fort Worth and Denver railroad, and about six miles northeast of Blue Grove. From this point the main line of Coleman Junction obviously turns eastward past Kola switch and on to the bluffs three miles north of Bellevue and two to three miles west of the Clay-Montague County line. However, the northward dip of the Coleman Junction and the gradient of the East Fork are almost identical. In consequence the Coleman Junction equivalent extends northward in a complicated fashion down the valley of the East Fork and an eastern branch of this fork extends as far north as Dickworsham switch. This was obviously mapped competently by McGowen and I have not retraced this area.

At the bluffs north of Bellevue the Coleman Junction leaves the East Fork drainage for that of Belknap Creek and turns northward, gradually descending the western slopes of that valley into western Montague County (with a number of outliers to

the east) and finally, about three miles east of Ringgold, disappears into the Belknap Creek alluvium and perhaps reaches the Red River, only about two miles to the north.

I have done little work east of Belknap Creek. North of a west-east line running past Belcherville and Nocona, bounded on the east by the Cretaceous and north by the Red River, is a triangular area which McGowen, I am told, found difficult to interpret and which I, studying it in more superficial fashion, found equally puzzling. A sandstone running eastward along the line mentioned is essentially equivalent to the Coleman Junction, and hence all of the area under consideration is presumably as high as the Admiral Formation, lying above the Coleman Junction, and McGowen found here several sandstone beds suggesting to him, I am told, that we are here dealing with a deltaic condition. On the other hand, Frank Gouin has pointed out to me that in the region of Lake Nocona there is a well-developed anticline, presumably connected with the Muenster arch, which brings relatively low strata to the surface. On the map I have merely indicated the lowest sandstones, which may be roughly Coleman Junction equivalents.

Elm Creek Limestone

The top member of the Admiral Formation, Elm Creek Limestone, appears on the 1937 map of Throckmorton County, running north-northeast from the neighborhood of Throckmorton to the Baylor County line not far west of the Brazos. This limestone has not previously been mapped further north. Entering Baylor County, this limestone is present in a river bluff across the river from Round Timber settlement, and is visible in a similar bluff east of the river near Round Timber. In between, however, the limestone follows a very circuitous course. It turns westward, gradually descending in elevation along the branches of Wagon Creek, and finally reaches the broad alluvial valley of the Brazos River at the foot of a bluff about two miles northwest of Round Timber. Across the river, at the mouth of a small creek two miles north of Round Timber, the limestone is seen on the north bank of the Brazos. The country from this point north and east toward Westover is flat agricultural land, but occasional exposures, mainly in highway ditches, show the Elm Creek to follow a circular course, about two miles north from the river, then about three miles east and then back southwest toward Round Timber — the limestone gaining some elevation

and becoming more readily traceable in this last part of its circuit.

For several miles east of Round Timber the ground is covered by river sands and the Elm Creek Limestone is not visible. Beyond this sandy area, however, the limestone can be followed (although with some difficulty) northward a bit west of the Baylor-Archer County line to reach the west side of Briar Creek, about four miles northeast of Westover and just west of the county line. From here the limestone runs (rather obscurely) northeast, west of Briar Creek and then, a mile or so north of the Seymour-Archer City highway, turns west and southwest into the valley of Godwin Creek. Here the situation is a confusing one. The Elm Creek is here a double limestone, and the dip of the beds is almost exactly equivalent of the slope downward to Godwin Creek, so that the two beds, prominently exposed, form a confusing pattern. The two beds gradually reach the creek level about four miles southwest of their first appearance in the eastern slopes, and then run north, poorly exposed, to cross the Little Wichita River above its junction with Godwin Creek. North of the river the limestone is better exposed, and gradually ascends the slopes, and crosses Slippery Creek about five miles south of Dundee.

A mile or so east of this creek the limestone disappears and (contrary to the usual condition in the Wichita beds) has no immediate sandstone continuation. However, well logs clearly show that the bed continues east at the foot of the bluffs south of Black Flat. East of that settlement the stratum, as shown by the subsurface, is continued along the north side of the valley of Plum Creek (locally termed Rattlesnake Canyon). However, beyond this point, five miles south of Mankins, the bed disappears into the flat prairies of the Holliday Creek valley and for the next six miles can only be traced by well logs, until a sandstone at an appropriate elevation appears in the Hull-Silk oilfield three miles south of Holliday. This runs eastward for five miles, forms a conspicuous bluff, and then turns north to disappear into the Holliday Creek alluvium.

Beyond this point the main outcrop is to be found only north of Holliday Creek and, farther on, north of the Big Wichita River. However, to the northeast there is a very extensive series of outliers, covering much of northern Clay County. Along the divide between the Big Wichita and Little Wichita rivers is a scattered series of outliers, with elevations somewhat over 1,000

feet, from the northeast corner of Archer County and the southeast corner of Wichita County into the western margin of Clay County, just east of the Wichita Falls-Henrietta highway and railroad, where the sandstone is present on a low hill at about 1,030 feet.

This marks the beginning of a large series of outliers covering much of northern Clay County. The beds here are much affected by the Electra arch structure, but with one conspicuous exception (mentioned later) this structure had become inactive by the time of deposition of the Elm Creek equivalent, and the beds are almost horizontal, lacking the northern dip seen farther south; for the most part the sandstones, which I believe equivalent to the Elm Creek, average about 950 feet above sea level. Except along the Big Wichita River there are few bluffs, and exposures are far from continuous along the gently rounded hills of the region. The major outlier is one covering the higher ground extending northeastward past Dean, Petrolia, and Byers. From the southwest corner, at the county line, its borders can be followed northward and then eastward around the valley of Duck Creek, eastward and then northwestward to the region of Dean, following the upper slopes of the valley of Turkey Creek. After running eastward for nearly ten miles, the outcrop turns northwest, to circle about the Petrolia oilfield just southeast of that town. The outcrop runs eastward again for four miles before turning northward again, to run along the upper slopes of small creeks running eastward into the Red River. There are further small outliers along the high ground east of Petrolia, the last of this series only a short distance west of the Stanfield community. The east side of the main outlier can be traced as far north as Byers. The bed, however, appears to continue about two miles north of this town, and then swings sharply southwestward, east of the Big Wichita River. Exposures generally close to the 950-foot level can be followed along this course for about 14 miles, to a point two and one-half miles NNW of Dean. Here the supposed Elm Creek Sandstone equivalent, as well as beds above and below, are turned up almost vertically, turn sharply to the northwest and disappear into the Big Wichita alluvium. Subsurface maps show the presence here of a marked syncline, presumably related to the Electra arch structure but representing an "adjustment" that took place at a much later date than formation of the arch structure. Two miles southwest of this area, the presumed Elm Creek Sandstone appears again east of

the Big Wichita and, running south close to the county line, reaches the hill mentioned above where the circuit of this major outlier was begun.

The main outcrop of the Elm Creek member, as determined by well logs, runs northeastward to Wichita Falls north of Holliday Creek, but is visible only in a few places north of Lake Wichita and south of Allendale. Returning westward south of the Big Wichita, it is well exposed for most of the way west for ten miles, when it disappears into the river alluvium. East of Iowa Park it appears north of the river, but there are only occasional exposures to plot its course eastward, south of Sheppard Air Force Base and the municipal airport, then on eastward north of the Big Wichita, past Friberg School and onward past Thornberry in Clay County to a point south of Charlie. East of this point the sequence is interrupted by the course of a former channel of the Red River but farther to the east, between the Red River and the Big Wichita, Pumpkin Ridge forms a conspicuous outlier. Excellent subsurface logs are present for this northernmost part of Clay County, and it is clear that the Elm Creek Sandstone turns northward, west of the old river channel and then west along the Red River bluffs (where possible exposures are largely covered by soil). Coming west into Wichita County, this member dips a bit southward into the valley of Gilbert Creek and a southern branch of this creek, and then vanishes into the Red River bottoms.

Bead Mountain Limestone

Bead Mountain Limestone, forming the boundary, has long been known to run northeast across Baylor County, and part of its course is shown on the 1937 cooperative map of that county (Garrett, 1937) and on the similar map of Wichita County. Locally it has been termed the Rendham Limestone in Baylor County and, farther north, the Beaverburk Limestone. In contrast to all lower members, it can be traced as a limestone all the way to the Red River. In southern Baylor County, it crosses the Brazos River about eight miles south of Seymour and, rising to the east, crosses Deep Creek and then forms the summit of east-facing bluffs as it runs northward on the west side of the Godwin Creek valley east of the former England settlement and the England cemetery. It crosses Daggett Creek near its head and then swings eastward for some miles (not

clearly seen) and becomes exposed in bluffs south of the Little Wichita River. Turning west, it descends to cross the Little Wichita as a limestone ledge about two miles east of Fulda station on the Wichita Valley Railroad. Turning eastward it can be readily followed for some miles and then, more obscurely, it can be seen to cross the Wichita Falls-Seymour railroad and highway just east of the Baylor-Archer County line. It now turns northward, presently forming a conspicuous bluff which, in an outlier, forms the southern margin of the dam of the Diversion Reservoir on the Big Wichita River. The limestone turns west up the south side of the river, and, since the dip of the beds and the slope of southern tributaries of the river are almost identical, has an intricate pattern. The outcrop runs southward up the valley to two small creeks west of the dam and then, west of the county line, strikes the valley of Brushy Creek up which it runs almost to the height of land and the Wichita Falls-Seymour railroad and highway. It then descends again north to the river bluffs, but three miles farther west encounters Boggy Creek, up which the Bead Mountain extends for about two and one-half miles. Beyond Boggy Creek the limestone reaches the river level about a mile west of the bridge leading from Fulda to "Sweetly Cruz" camp. North of the river the limestone descends to the Diversion Lake dam, keeping (as would be expected) close to the lake level. Below the dam the Bead Mountain runs to the northeast (Fischer, 1937) along the bluffs north of the Big Wichita, for some six miles, then turns west to descend into the Beaver Creek valley, crossing that creek about two miles east of the Wilbarger County line. Its course from this point east up onto and along the ridge north of Beaver Creek and the Big Wichita, and then back south of Beaver Creek, to a point southeast of Fowlkes Station on the Fort Worth and Denver railroad, is shown on the 1937 cooperative map of Wichita County. Until this present study it was unknown beyond a point north of Beaver Creek about six miles west of Iowa Park. I have, however, been able to trace it north to the Red River. In contrast to its strength farther west, the Bead Mountain here is thin and sandy in nature. The country between this point and the Red River is flat, with few exposures, but through occasional small exposures, mainly in road cuts, I have been able to plot its general course, northward and then eastward around the headwaters of North Buffalo Creek, Lost Creek and Stevens Creek, then over a low divide to follow the

north side of the Gilbert Creek valley northeast nearly to Burkburnett. The deeper beds here are much disturbed in relation to the Electra arch, but this structure appears to have become inactive by the time of deposition of the Bead Mountain, and the surface beds here are nearly horizontal. For a short distance, near Burkburnett, no exposures of the Bead Mountain Limestone are seen, but turning west, it is occasionally visible in the slopes south of Wildhorse Creek, which it crosses about two miles northeast of Clara. It then attains the south bluff of the Red River, where it is clearly visible in the cuts of two roads which descend to the river bottoms northeast of Clara. It descends to the west, and reaches the level of the Red River alluvium north and a short distance west of Clara.

Leuders Limestone

The Leuders, now generally regarded as a formation, has long been recognized as the top of the Wichita beds, separating them from the Clear Fork. I have not studied the Leuders in detail. Several members are shown in the 1937 cooperative map of Baylor County, crossing the Brazos in the "canyon" of that river below Seymour and running north past Maybelle and the Kemp Lake dam. I do not know of any detailed mapping of the Leuders in Wilbarger County; this limestone series crosses Beaver Creek in the central part of the county and then, as stated by Wrather (1917) trends northeast toward Harrold. It appears to be represented by sandy limestones farther northeast, along the lower course of China Creek, toward the Red River.

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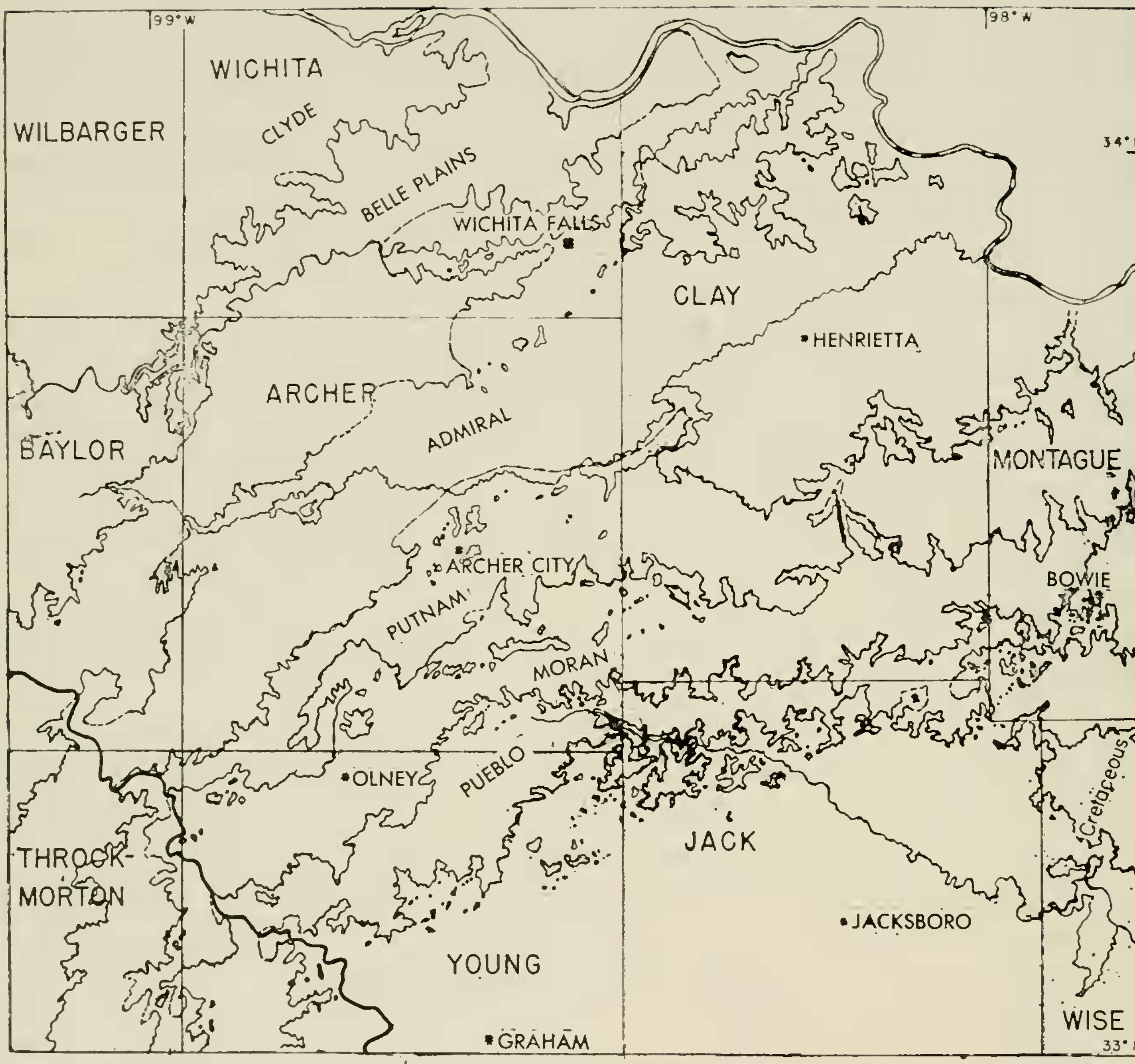
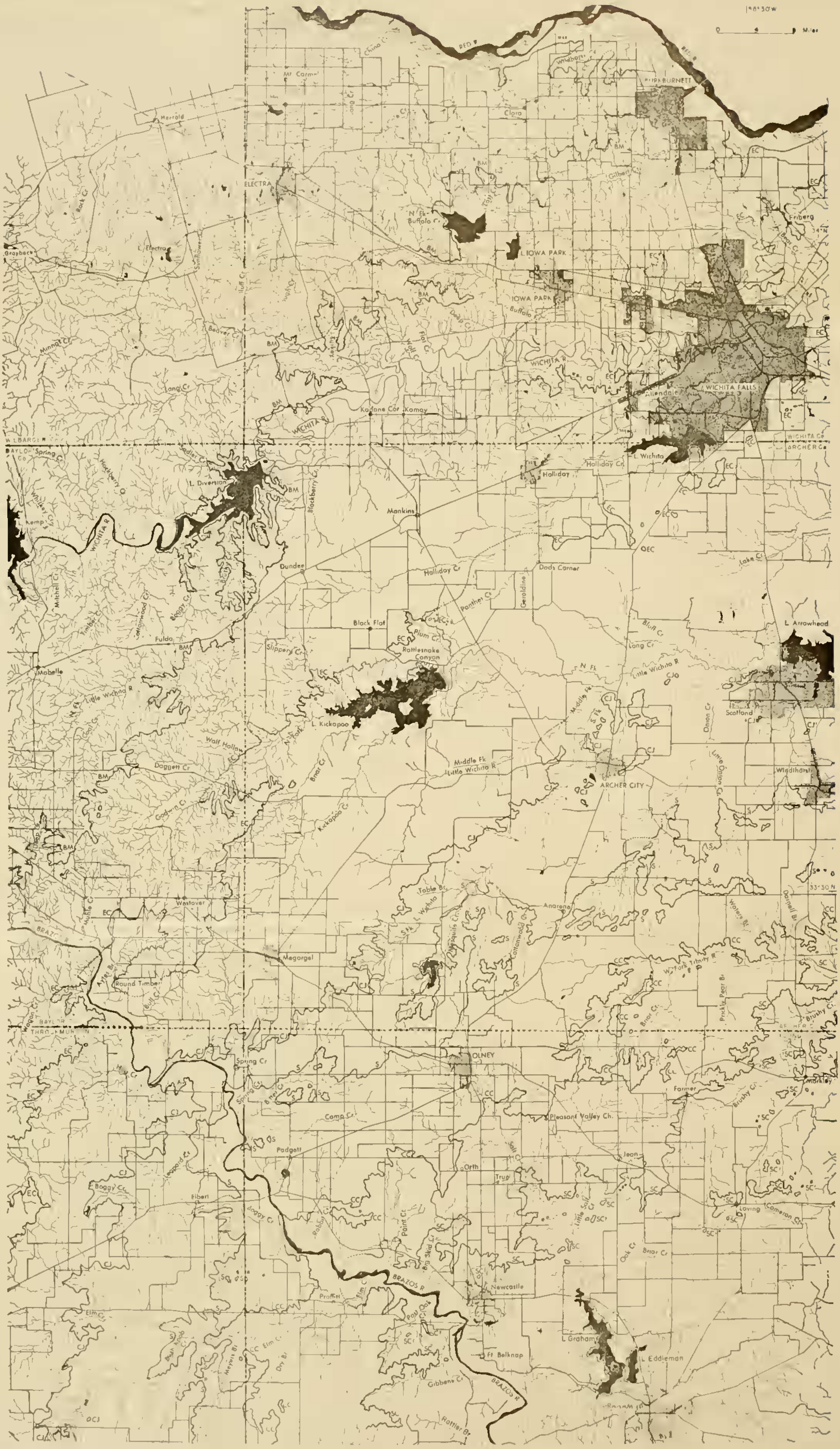
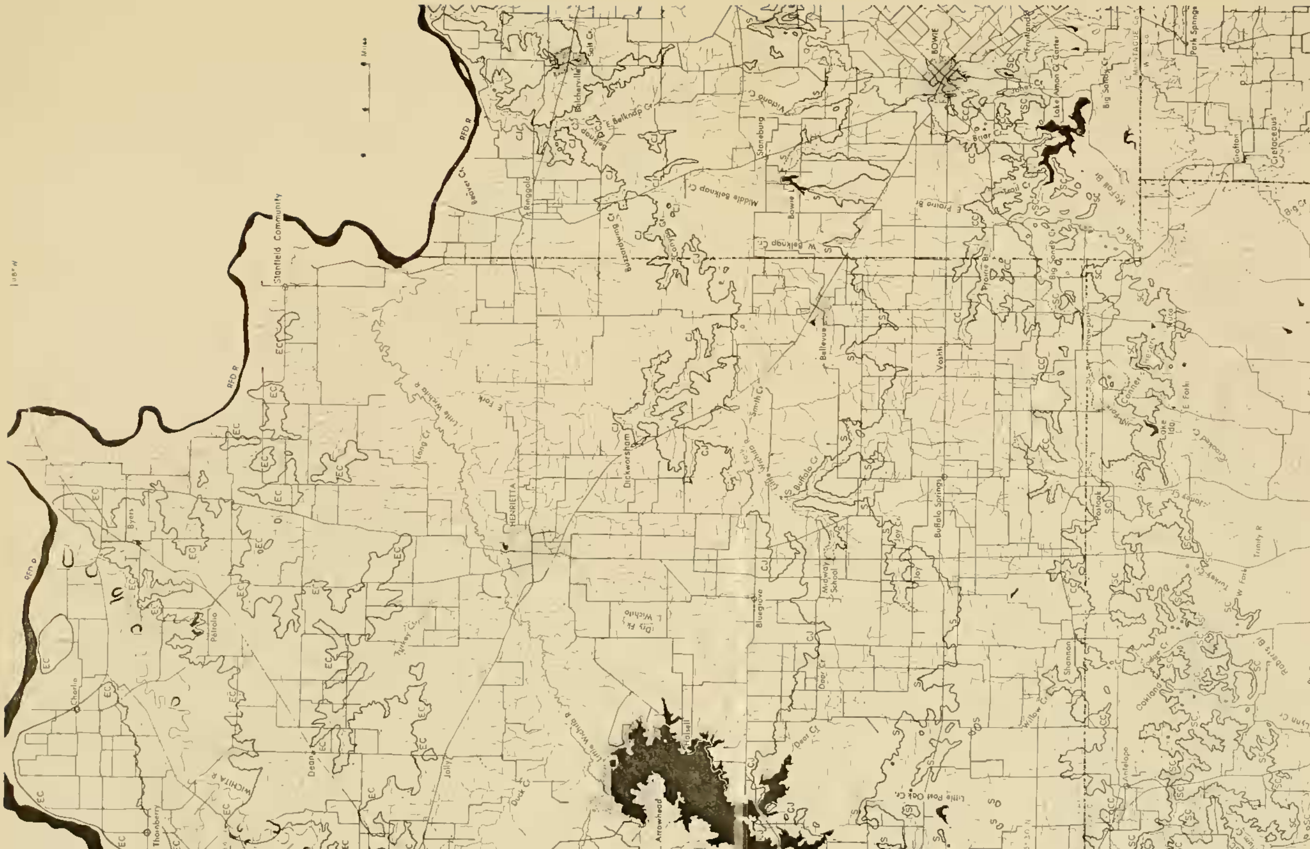


Map. 1. General area of north-central Texas showing where members of the Wichita redbeds are exposed.



Map 2. Western section of the region shown in Map 1, giving in detail tracings of the various members of the Wichita Formation. Abbreviations. *BM*, Bead Mountain Limestone; *CC*, Camp Colorado Limestone; *CJ*, Coleman Junction Limestone; *EC*, Elm Creek Limestone; *S*, Sedwick Limestone; *SC*, Saddle Creek Limestone; — . . . . — . . . Cretaceous boundary.



Map 3. Eastern section of the region shown in Map 1, giving in detail tracings of the various members of the Wichita Formation. Abbreviations: *BM*, Bead Mountain Limestone; *CC*, Camp Colorado Limestone; *CJ*, Coleman Junction Limestone; *EC*, Elm Creek Limestone; *S*, Sedwick Limestone; *SC*, Saddle Creek Limestone; — . . . — . . . Cretaceous boundary. (Ed. note: Because Maps 2 and 3 were drawn from a large number of different maps at different scales, their north south alignment is not exact.)